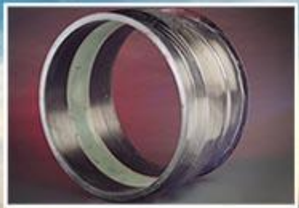
National Aeronautics and Space Administration

Advanced Air Vehicles Program



Advanced Composites Project Overview

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September 16, 2015

Outline

- Motivation
- Project Goal
- Project Organization
- Project Technical Challenges
- Example Highlights

Motivation

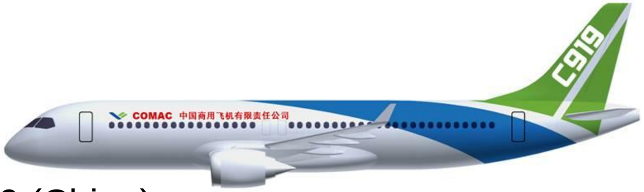
- **Growing use of composite materials:**

Boeing 787 GE Genx

Lockheed Martin F-35

Northrop Grumman
Fire Scout

Airbus
A-350 XWB



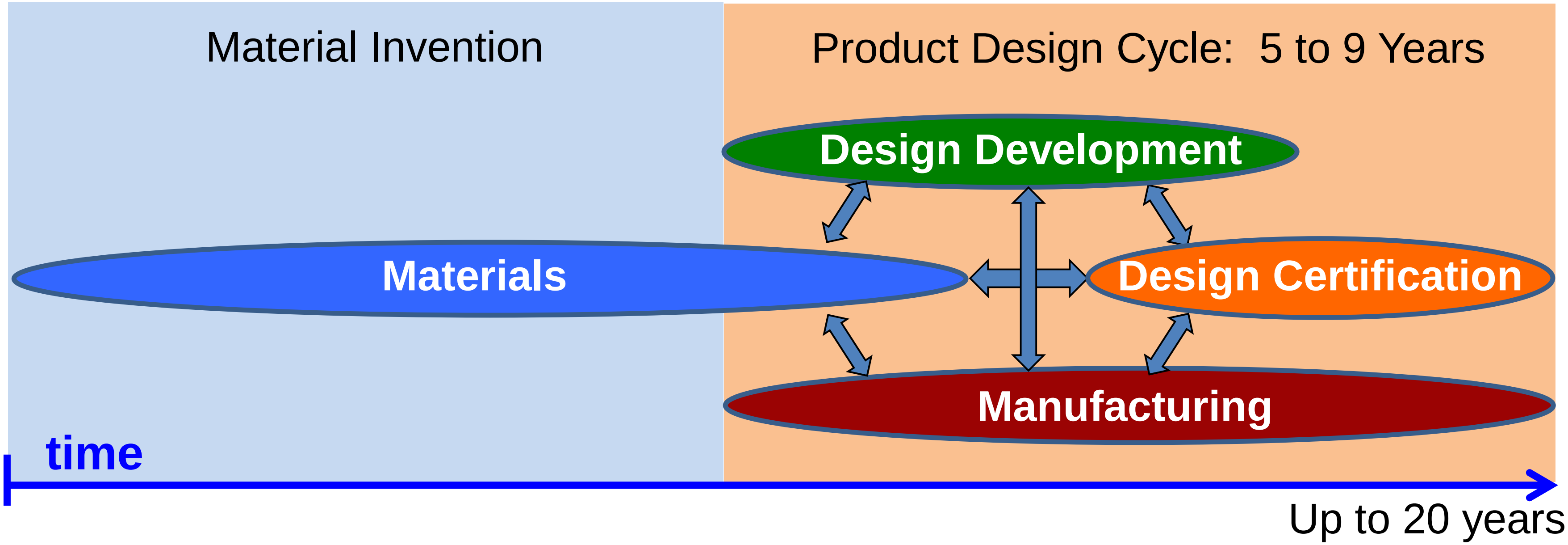
Comac C919 (China)

Bombardier
C-Series

Sukhoi Superjet 100
(Russia)

- **Benefits of composites:** • Lightweight • Durable • Low cost
- **Challenges:** Immature capabilities limit use and rate of innovation

Challenges in Composites Development/Certification

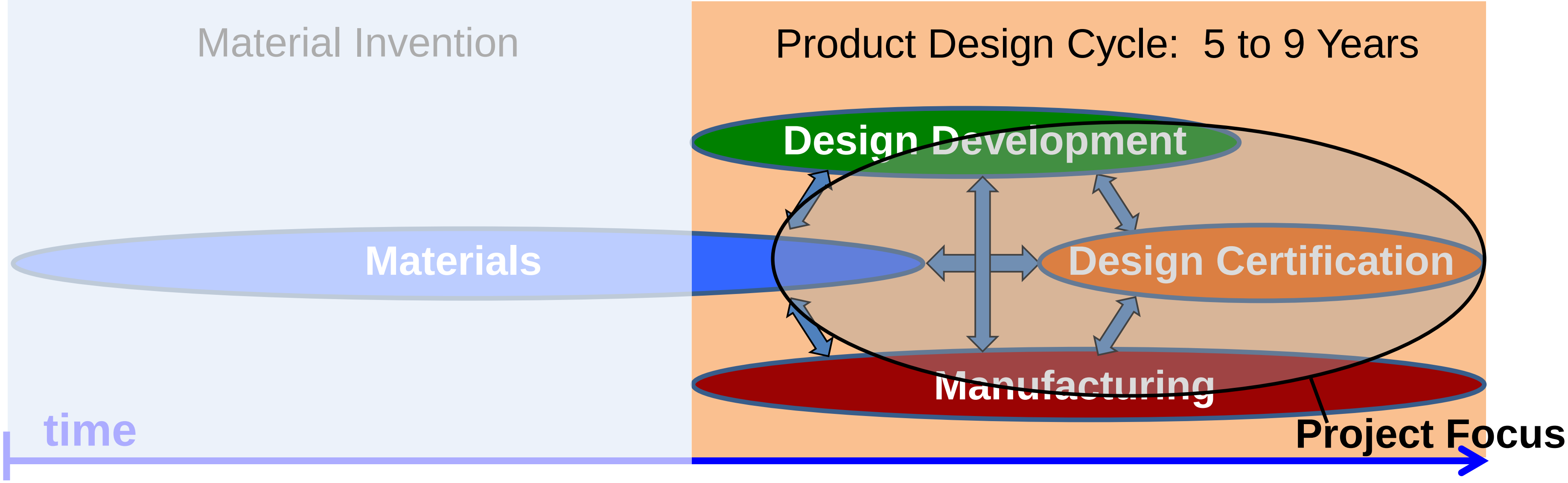


<u>Challenges with Composites</u>

- Complexity: parameters in construction; failure modes; variability
- Strength and life cannot be predicted reliably
- Strong dependency between design and manufacturing
- Empirical and iterative 'trial and error' methods; lots of testing
- NDE is painfully manual (human factors) and time intensive
- Redesigns and reworks: largest single factor in development time
- Simulation tools: Long lag for confidence to use models

Advanced Composites Project (AC)

Charter: Focus on reducing the time to develop and certify composite materials and structures, helping American industry retain their global competitive advantage in aircraft manufacturing



Goal: Reduce product development and certification timeline by 30%

Approach:
- Computational and experimental methods
- Damage and manufacturing process sym.
- Rapid inspection and characterization
- Gov't. – Industry – University team

Resources and Facilities:
- ~40 Civil Servant Workforce
- ~ $25M annual budget (full cost)
- NASA Centers: LaRC (host), Glenn and Ames (partners)

Team Approach: NASA and Partners

- Fundamental understanding of the science and physics
- High fidelity analysis and experimental methods
- Independent validation of methods
- Coordination of Working Groups

NASA

- Understanding of requirements
- Design and manufacture; production quality test articles
- Applied research expertise
- Validation testing and data sets
- Development of standard practice

Industry

Academia

- Expertise in fundamentals: supporting damage models, process models, data processing

FAA

- Advice with certification aspects
- Safety implications and practicality in application

Advanced Composites Consortium (ACC): public-private partnership for collaborative gov't – industry research

Advanced Composites Consortium (ACC)

- **ACC formation complete, Jan. 2015**
  - Founding members:
    - NASA, FAA
    - Boeing, GE Aviation, Lockheed Martin, United Technologies Corp., National Institute of Aerospace (Integrator)
  - 50/50 cost sharing
  - Collaborative research tasks with multiple partner teams

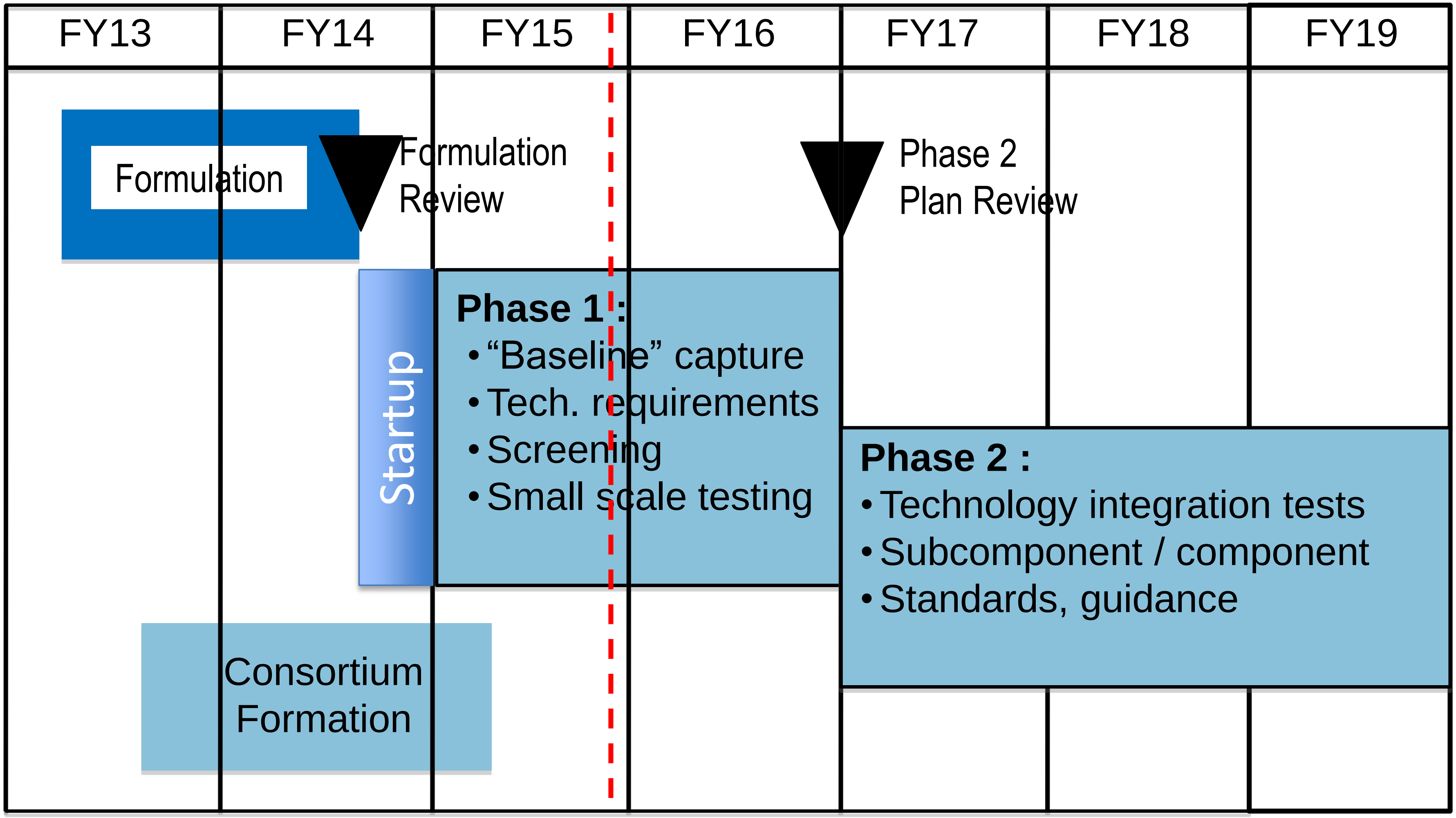
- **Membership:**
  - Execute now with current members
  - Strategic planning to add participants (sub-contractors, new members)
    - Next 3-6 months to participate in current Phase 1 tasks
    - Again in 2016 for Phase 2

Executive Steering Committee

Technical Oversight Committee

Cooperative Research Teams

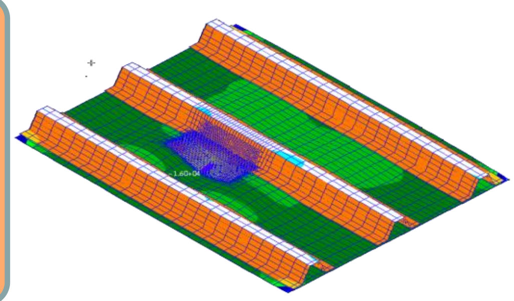
Advanced Composites Project Flow:

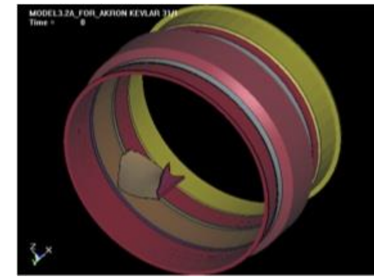


AC Technical Challenges

Accurate Strength & Life Prediction

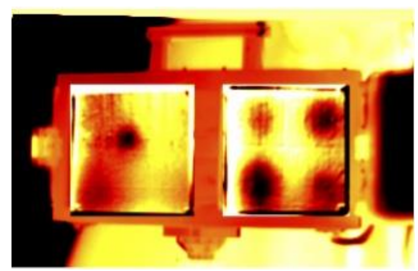
- Reduce design and testing effort / time
- Robust high-fidelity analysis for damage
- Better prelim design, fewer redesigns





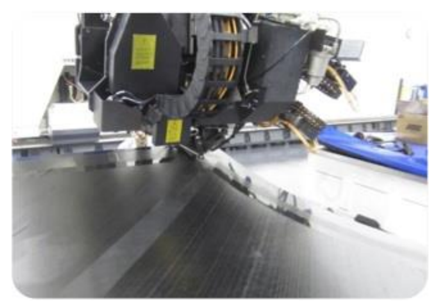
Rapid Inspection & Characterization

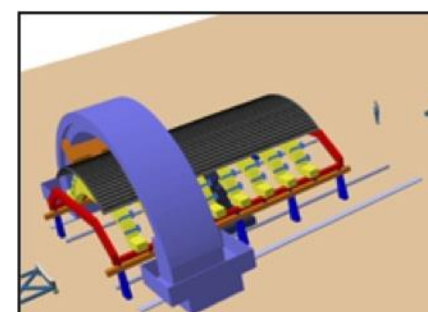
- Increase inspection throughput by 30%
- Quantitative characterization of defects
- Automated inspection



Efficient Manufacturing Process Development

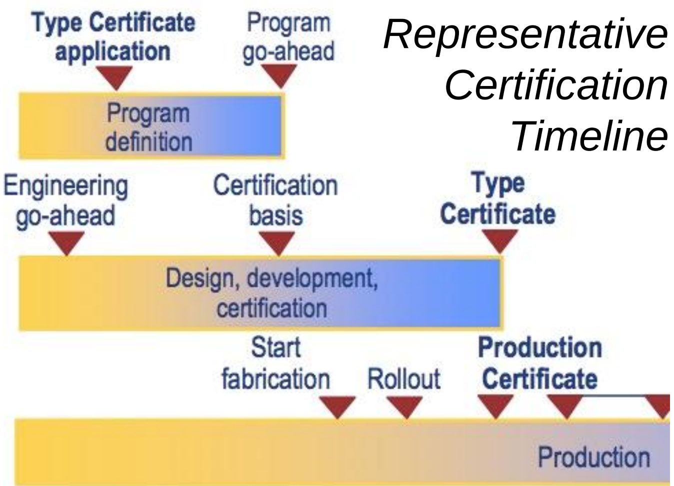
- Reduce manufacture development time
- Fiber placement and cure process models to predict defects
- Improve quality control





Phase 1 Deliverables

Representative Certification Timeline

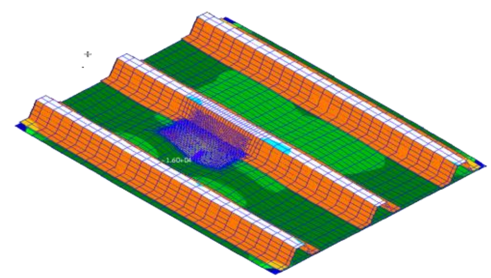


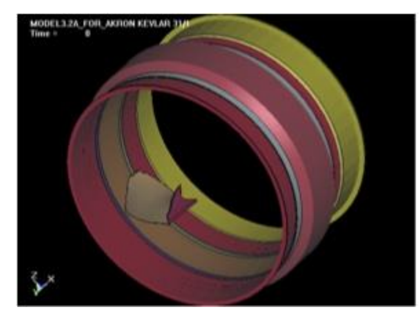
Systems Engineering

1. Development to Certification Timeline (DCT)
2. Performance measures for technologies
3. Measure of Phase 1 progress in time reduction
4. Phase 2 plan: select concepts and technology

TC1: Accurate Strength & Life Prediction

1. Ranking of modeling approaches & identify key gaps based on 1st Level BB Testing
    a. Post Buckled Panel with BVID, Strength and Life
    b. Engine Fan Containment
    c. Open Rotor Shields
    d. Rotor Blade Spar Fatigue
2. Ranking of proposed design tools to improve integrated design

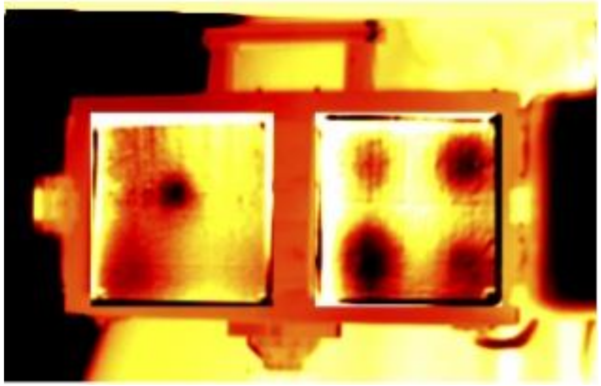




Phase 1 Deliverables (cont.)

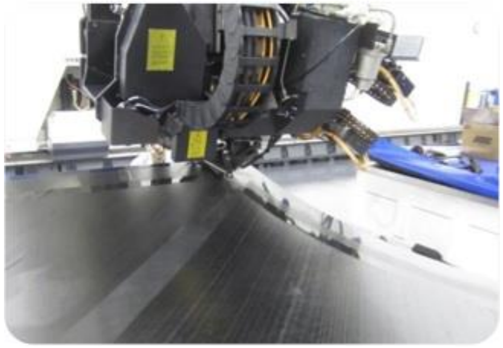
TC2: Rapid Inspection & Characterization

1. Ranking of critical defects
2. Test standards for assessment & validation
3. Ranking of tools & implementation approaches



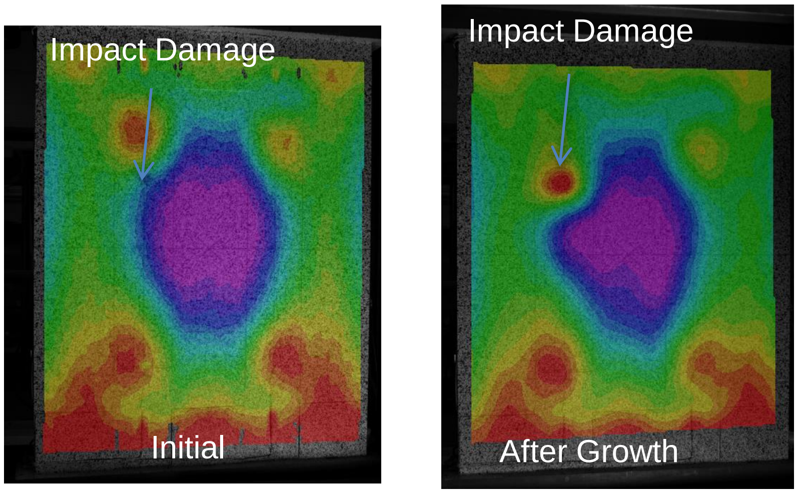
TC3: Efficient Manufacturing Process Development

1. Ranking of AFP Defects
2. Beta version of DFM software
3. Defect prediction through Beta validation of process models: AFP, co-cure bonding, cure

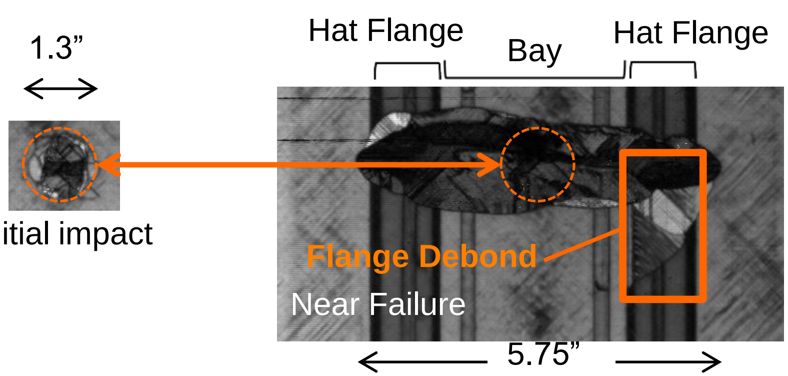


Highlights from Recent Research

3 stringer stiffened panel with BVID



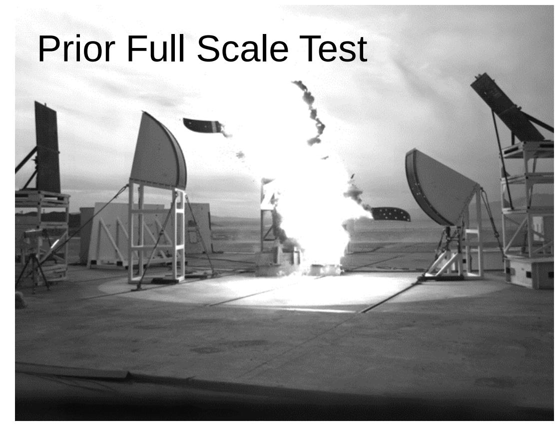
Change in deformation with damage growth

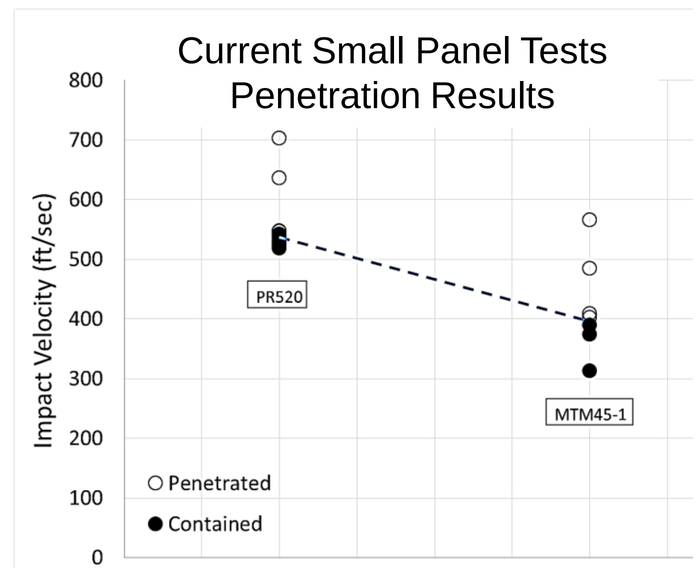


Ultrasonic scan showing damage growth

- Damage data to evaluate failure models
- Insitu NDE: Digital image correlation, acoustic emmision, thermography, non-immersion UT

Fuselage Shielding





- Data from small panel tests improves model correlation for full scale test
- Aid in design of future test articles

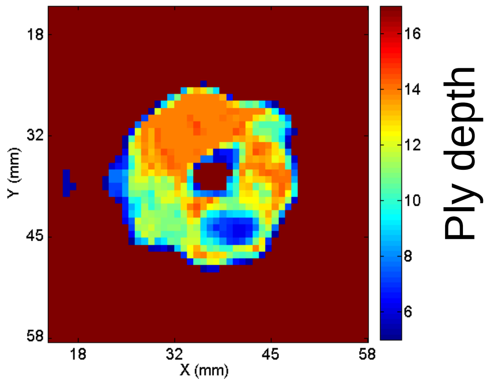
Highlights from Recent Research (cont.)

Progressive Damage Analysis Methods: State of the Art Assessment

- SoA reviews conducted by four industry partners
  - United Technologies, Boeing, Lockheed, Northrop
- Methods evaluated for applicability, maturity, validation to three case studies
  - Static: Residual strength of postbuckled stiffened panel with BVID
  - Fatigue: Dynamic rotor components
  - Dynamic: Containment of engine fan blades
- Sources: questionnaires to code developers, literature surveys, and interviews
- Industry evaluations of PDA tools in agreement for some case studies and varied for others
- No tool was perfect. The “right” answer is probably a combination of tools.
- **Next step**: Cooperative Reseach Teams will select PDA tools for further development & evaluation within their specific case study

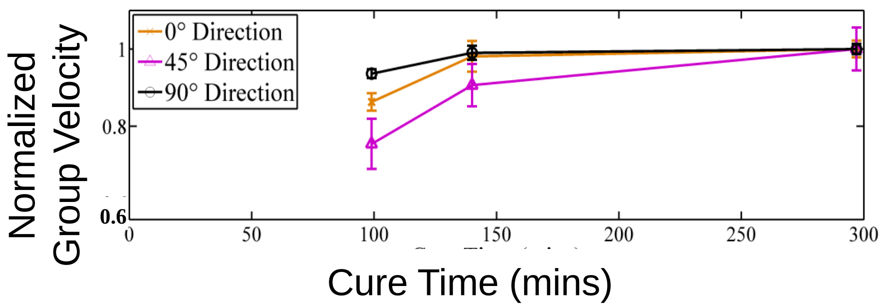
Highlights from Recent Research (cont.)

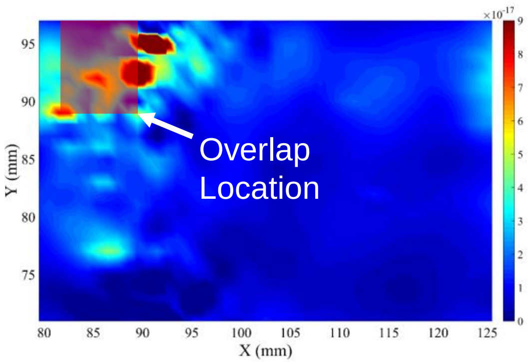
NDE: Delamination size and depth



- Developed single sided non-contact method for delamination damage characterization using laser vibrometry ultrasonic wavefield analysis
- Enables rapid contactless inspection of large parts once multi-beam laser vibrometers are available

Manufacturing monitoring

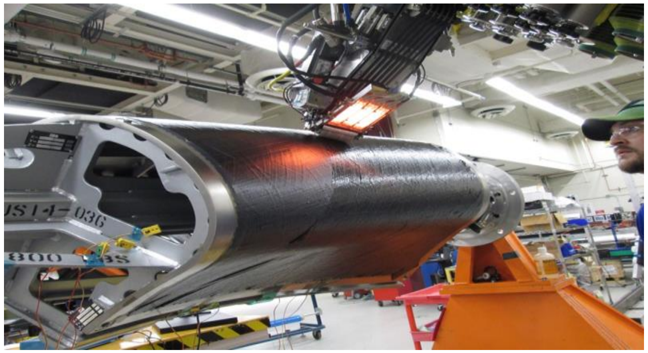




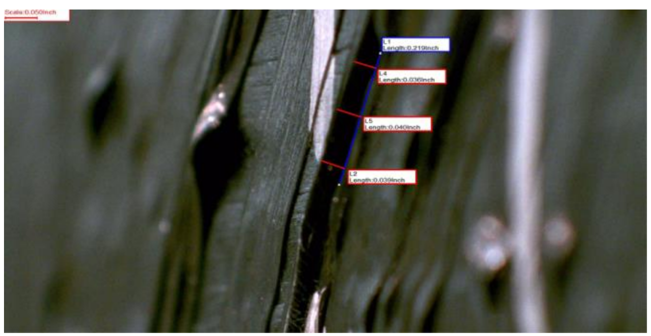
- Developed technique to monitor degree of cure, measuring group velocity of Lamb waves from piezoelectric devices
- Developed technique to detect and size ply overlap defects, using guided wave from air-coupled transducer and zero lag cross-correlation imaging metric

Highlights from Recent Research (cont.)

Manufacturing defect design of experiments



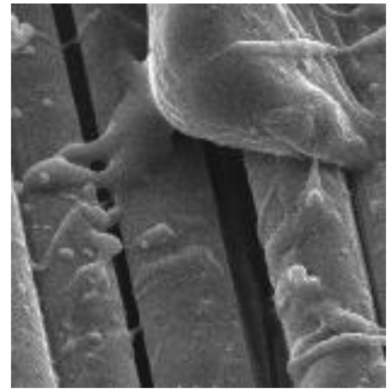
Automated Fiber Placement (AFP) DOE of complex curvature part at Boeing



90^{o}-ply puckering defects recorded

- AFP processing DOE at Boeing: temp., speed, compaction, and tape tension
- Results to be used to develop process model

Bond surface prep



SEM: Laser ablation surface treatment

SEM: Grit blast surface treatment

- Demonstrated that laser ablation treatment can remove surface contaminants without significant exposure of or damage to fibers

ISAAC system operational at LaRC

Testbed for:

- In-situ inspection techniques
- Effects of AFP defects
- Creating cure process models
- Developing design for manufacturing software

Interagency Coordination: National Plan

<u>Goal:</u> Technology Gap Assessment to Guide National Research & Development (R&D) Efforts Aimed at Structural Certification and Continued Airworthiness

<u>Steering Committee:</u>

- Air Force
- Army
- Navy
- NASA
- FAA
- DARPA

<u>OEM Certification Representatives</u>

- Bell Helicopter
- Boeing
- Lockheed Martin
- Northrop Grumman
- Sikorsky

Summary

- Advanced Composites Project has goal to reduce time to develop and certify composite structures, to aid U.S. industry
- Teaming approach: NASA, FAA, Industry, and University; collaborative tasks
- Advanced Composites Consortium established as public private partnership
- Phase 1 projects to complete in Sept. 2016
- Phase 2 to complete in 2019:
  - Working tools demonstrated for sub-component or component level structures
  - Tools transitioned to industry, documented in guidance material
- Executing in close coordination with other Gov't. agencies